# The effect of cooking and freezing on the carapace length of the American lobster (*Homarus americanus*)

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Vitaliev, Vl., B. Fremette and F. Savoie. 2003. The effect of cooking and freezing on the carapace length of the American lobster (*Homarus americanus*). Can. Ind. Rep. Fish. Aquat. Sci. 269: v+12p.

In the southern Gulf of St. Lawrence, there were concerns that freezing mixed American lobster (*Homarus americanus*) to preserve evidence for the court could potentially reduce the carapace length, and compromise the enforcement of a fishery regulation limiting minimal legal size. Tests were performed on 30 soft- and 30 hard-shell American lobsters to study the potential for shrinkage when lobsters were cooked and/or frozen. It was found that carapace length reduction was related to the carapace condition. Except for freezing of soft-shell lobsters, all treatments produced a statistically detectable reduction in carapace length. However, the average carapace length reduction ranged from only 0.1 ± 0.7 mm, the highest increase being for hard-shell lobsters after cooking, freezing then thawing (t-test, P-value= $1.0 \times 10^{-14}$). Out of the 60 animals studied, none had a carapace length reduction over 0.7 mm, while four had a carapace length increase. Although a carapace length reduction could be detected statistically, this should not cause problems in enforcing a minimum legal size.

Keywords: American lobster, *Homarus americanus*, carapace length, cephalothorax, lobster shell.



Vitaliev, Vl., B. Fremette, and F. Savoie. 2003. The effect of cooking and freezing on the carapace length of the American lobster (*Homarus americanus*). Can. Ind. Rep. Fish. Aquat. Sci. 269: v+12p.

Dans le sud du golfe du Saint-Laurent, des inquiétudes ont été exprimées au sujet des effets possibles de la congélation du homard américain (*Homarus americanus*) sur la longueur de la carapace. En effet, il est pratique courante de congeler les homards saisis en attendant la tenue du procès et la possibilité qu'une telle pratique entraîne une diminution de la longueur de carapace pourrait nuire à l'application des mesures de gestion concernant la taille minimale légale. Une étude a donc été menée sur 30 homards de carapace dure et 30 de carapace molle afin d'étudier les effets de la congélation et/ou la cuisson sur la longueur de carapace des homards. Il s'avère que la modification de la taille de carapace est reliée à la condition de la carapace du homard. À l'exception de la congélation de homards de carapace molle, tous les traitements ont entraîné une légère diminution de la longueur de carapace. Cependant la diminution moyenne de la longueur de carapace n'était que entre 0.1 et 0.7 mm, la plus grande diminution s'ayant produit lorsque les homards ont été cuits puis congelés (t-test, seuil observé= $1.0 \times 10^{-14}$). Parmi les 60 animaux étudiés, la plus forte diminution observée de la longueur de carapace est de 0.7 mm alors que quatre homards ont subit une augmentation de leur longueur de carapace. Malgré la diminution statistiquement significative de la longueur de carapace du homard, une diminution de l'ordre observé ne devrait pas être un problème pour l'application d'une taille minimale légale.

Mots clés : Homard, *Homarus americanus*, longueur de carapace, céphalothorax, carapace du homard.

## [illegible]

The american lobster (*Homarus americanus*) fishery is the most valuable coastal fishery in the northeast (Atlantic) [illegible] (ASMFC). Although the ASMFC lobster fishery is managed through five fishing areas ([illegible]) (Fig. 1) and two fishing seasons (spring and summer/fall), minimum carapace length is a common management tool used in all [illegible]. Carapace length (CL) is defined as the length from the posterior rim of the eye socket to the back of the carapace, parallel to the mid-dorsal line. If post-catch handling of lobsters modifies their CL, there is potential for problems with the enforcement of a minimum CL regulation. In [illegible], there was a concern that soft lobsters (*Homarus americanus*) could potentially shrink during cooking. Ma[illegible] et al. (2001) concluded that there was no statistically detectable effect on the CL. Recently, questions were raised concerning the possible effect of freezing on the CL of lobster, since it is a common procedure to freeze-record lobsters in order to preserve evidence for the court.

This study examines the effect of freezing on the CL of American lobster as well as the effects of cooling and cooling followed by freezing. Experiments were conducted on both soft-shell and hard-shell lobsters to cover the lobster's physiological stages during the two fishing seasons in the [illegible].

## [illegible]

Two treatments were considered in the study: (1) freezing of live animals, and (2) cooling of live animals followed by freezing, with each treatment being applied to soft and hard-shell lobsters. The experiment was carried out in two time periods to account for the seasonality in shell condition; soft-shell lobsters being related to newly molted animals (July-September) while hard-shell lobsters are considered late post-molted lobsters (October-June). The experiment on soft-shell lobsters took place from August 21 to 26, 2002, and the one on hard-shell lobsters, from October 9 to 17, 2002. All lobsters used for this study came from holding tanks of the same processing plant, which is supplied by 12 different fishermen fishing in [illegible]. Lobsters had been in holding tanks for no more than 3 days. The water in the tanks had been held at the same salinity as the nearby seawater and at a constant temperature of 7 °C to 8 °C (original temperature 10°F to 15°F). A total of 36 lobsters were used for each shell condition and only lobsters within 1 mm of the legal size were selected. The minimum legal CL in [illegible] is 82.6 mm (3.25 in). All lobsters were alive and vigorous at the start of the experiment.

At the beginning of each experiment, the 18 males and 18 females lobsters were randomly divided into two groups of 18, and identified as their claws by a unique combination of rubber bands used to keep them closed. The rubber bands were also numbered with a permanent ink marker. Shell firmness criterion (i.e. *Russell-Hegre pressure test*) suggested by Jones (1977) was used to determine the shell condition for the soft-shell experiment at the lobster processing plant. At the lab, the carapace hardness of hard-shell lobsters was determined by two successive readings (Model 01185, ITC Instruments[TM]) on the cephalothorax, one at the anterolateral region (point A, Fig. 1 (a)) and the other at the posterior portion of the dorsolateral region (point B, Fig. 1 (b)). The durometer is a spring-driven gauge that measures the elasticity or hardness of a material on a scale of 0 to 100. The durometer was not used for soft-shell lobsters in order to avoid breaking the carapace. A lobster was classified as hard-shell when the readings at points A and B were above 70, and soft-shell when at least one of the two readings were below 70 (Conklin and Jarvis 2001). Furthermore, a physical reading was performed on all lobsters from the October sample to confirm that they were in the postmolt period (Aiken and Waddy 1980).

The carapace length of lobsters was randomly measured twice at each step in the experiment using an electronic caliper (Model 01314, Mitutoyo Corporation[TM]) (Fig. 1 (c)). For both the soft- and hard-shell experiments, all lobsters were first measured alive. One group of 18 lobsters was then frozen at −20 ± 1°C. The other group of 18 lobsters was cooked in boiling saltish water for 17 min and then cooled down for 1 hr at room temperature (20 ± 1°C). The lobsters were measured again after cooking but frozen as the uncooked ones. After 48 hr, lobsters were measured frozen but left to thaw at room temperature (20 ± 1°C) for 9 hr, and measured for the last time. In order to avoid manipulation variation, the same individual performed all lobster measurements and another individual recorded the measurements.

Statistical tests were carried out on the average of the two random measurements to compare CL before and following the two treatments. Differences in average CL before and after processing were tested using a one

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**Table 1.** Average CL differences between live and cooked and/or frozen lobsters for soft- and hard-shell, statistical significance for a one-sided t-test of the average difference being zero and 95% confidence intervals. Negative CL values indicates length increases.

| Treatment | Shell condition | Average carapace length difference (mm) | Statistical significance | 95% Confidence interval for difference |
|---|---|---|---|---|
| Freezing only | Soft (August) | 0.0 | 0.14 | (-0.1 ; 0.0) |
| | Hard (October) | 0.1 | 0.003 | (0.0 ; 0.1) |
| Cooking only | Soft (August) | 0.2 | $7.6 \times 10^{-7}$ | (0.2 ; 0.3) |
| | Hard (October) | 0.4 | $0.5 \times 10^{-10}$ | (0.3 ; 0.4) |
| Cooking and freezing | Soft (August) | 0.3 | $1.2 \times 10^{-7}$ | (0.2 ;0.4) |
| | Hard (October) | 0.5 | $1.5 \times 10^{-11}$ | (0.4 ; 0.5) |

**Table 2.** Observed frequencies (percentages) of the average difference in CL between live and frozen lobsters. Negative values indicate CL increases.

| Difference observed in CL (mm) | Soft-shell (n/15) | Hard-shell (n/15) | Total (n/30) |
|---|---|---|---|
| -0.1 | 3 (20.0%) | 1 (6.7%) | 4 (13.3%) |
| 0.0 | 10 (66.7%) | 5 (30.0%) | 15 (50%) |
| 0.1 | 1 (6.7%) | 2 (13.3%) | 3 (10%) |
| 0.2 | 1 (6.7%) | 4 (26.7%) | 5 (16.7%) |
| 0.3 | 0 | 3 (20.0%) | 3 (10%) |
| 0.4 or more | 0 | 0 | 0 |

**Table 3.** Observed frequencies (percentages) of the average difference in CL between live and cooked only lobsters. Negative values indicate CL increases.

| Difference observed in CL (mm) | Soft-shell (n/15) | Hard-shell (n/15) | Total (n/30) |
|---|---|---|---|
| -0.1 | 0 | 0 | 0 |
| 0.0 | 1 (6.7%) | 0 | 1 (3.3%) |
| 0.1 | 0 | 0 | 0 |
| 0.2 | 2 (13.3%) | 0 | 2 (6.7%) |
| 0.3 | 7 (46.7%) | 5 (30.0%) | 12 (40%) |
| 0.4 | 2 (13.3%) | 3 (20.0%) | 5 (16.7%) |
| 0.5 | 3 (20.0%) | 7 (46.7%) | 10 (33.3%) |

**Table 4.** Observed frequencies (percentages) of the average difference in CL between live and cooked then frozen lobsters. Negative values indicate CL increases.

| Difference observed in CL (mm) | Soft-shell (n/15) | Hard-shell (n/15) | Total (n/30) |
|---|---|---|---|
| -0.1 | 0 | 0 | 0 |
| 0.0 | 1 (6.7%) | 0 | 1 (3.3%) |
| 0.1 | 0 | 0 | 0 |
| 0.2 | 0 | 0 | 0 |
| 0.3 | 10 (66.7%) | 3 (20.0%) | 13 (43.3%) |
| 0.4 | 2 (13.3%) | 2 (13.3%) | 4 (13.3%) |
| 0.5 | 1 (6.7%) | 7 (46.7%) | 8 (26.7%) |
| 0.6 | 1 (6.7%) | 2 (13.3%) | 3 (10%) |
| 0.7 | 0 | 1 (6.7%) | 1 (3.3%) |

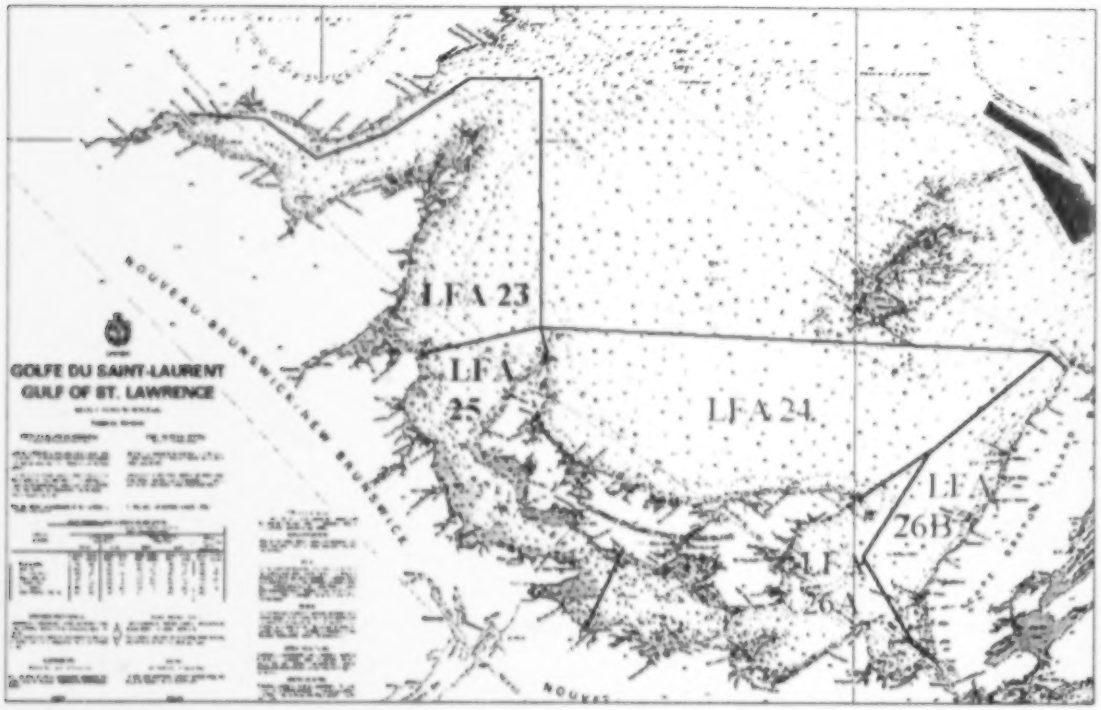


**Figure 1.** Lobster Fishing Areas (LFA) in the southern Gulf of St. Lawrence.

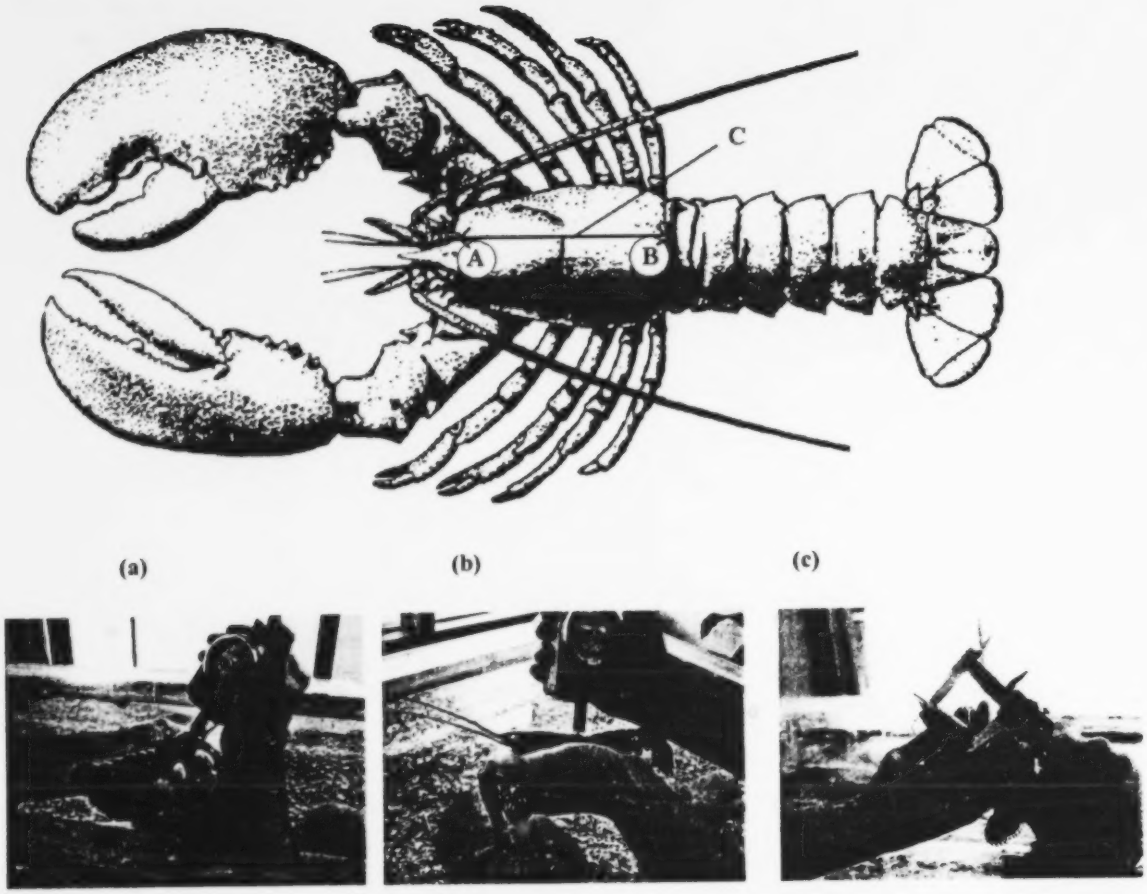


**Figure 2.** Durometer reading positions on the cephalothorax (a) anterodorsal region A and (b) dorsolateral region B, as well as (c) the measurement of the lobster carapace length with an electronic caliper.

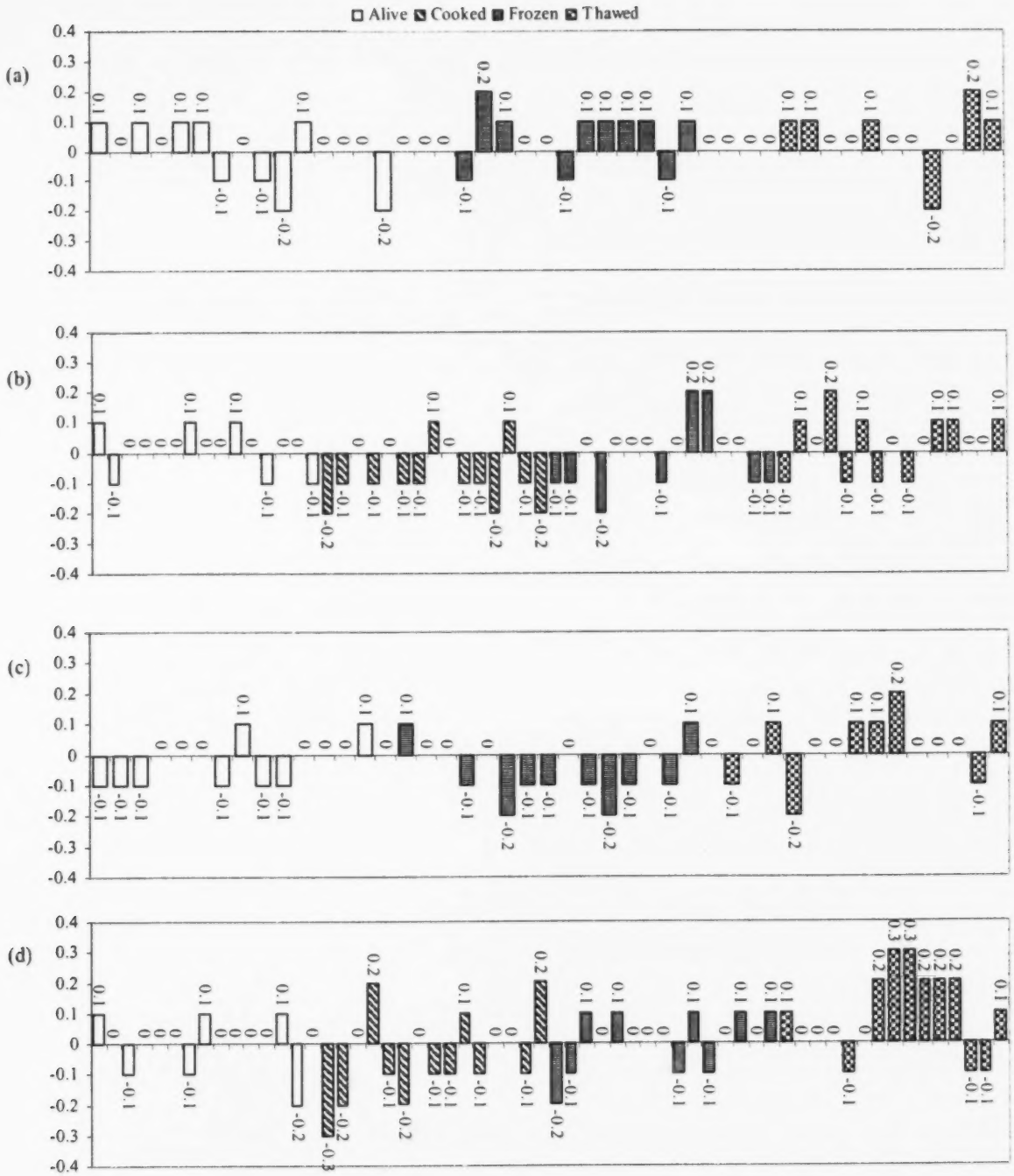


**Figure 3.** Difference between the two random measurements of the carapace length (mm) at any given post-catch handling stage for (a) soft-shell frozen (b) soft-shell cooked-frozen (c) hard-shell frozen and (d) hard-shell cooked-frozen lobsters.

## APPENDIX 1

Carapace length measurements (mm) and averages used for analyses

(a) Soft-shell, from August 23 to 26, 2002 (Live - Frozen -Thawed)

| Lobster | Sex | Live CL | | | Frozen CL | | | Thawed CL | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | Average | 1 | 2 | Average | 1 | 2 | Average |
| 1 | F | 69.3 | 69.2 | 69.3 | 69.2 | 69.2 | 69.2 | 69.3 | 69.3 | 69.3 |
| 2 | F | 68.2 | 68.2 | 68.2 | 68.2 | 68.2 | 68.2 | 68.1 | 68.1 | 68.1 |
| 3 | M | 68.2 | 68.1 | 68.2 | 68.1 | 68.1 | 68.1 | 68.2 | 68.2 | 68.2 |
| 4 | F | 67.3 | 67.3 | 67.3 | 67.2 | 67.3 | 67.3 | 67.4 | 67.4 | 67.4 |
| 5 | F | 69.4 | 69.3 | 69.4 | 69.5 | 69.3 | 69.4 | 69.5 | 69.4 | 69.5 |
| 6 | F | 68.3 | 68.2 | 68.3 | 68.3 | 68.2 | 68.3 | 68.3 | 68.2 | 68.3 |
| 7 | M | 67.0 | 67.1 | 67.1 | 66.9 | 66.9 | 66.9 | 67.1 | 67.1 | 67.1 |
| 8 | M | 66.8 | 66.8 | 66.8 | 66.8 | 66.8 | 66.8 | 66.8 | 66.8 | 66.8 |
| 9 | F | 69.0 | 69.1 | 69.1 | 69.1 | 69.2 | 69.2 | 69.2 | 69.1 | 69.2 |
| 10 | F | 70.0 | 70.2 | 70.1 | 70.2 | 70.1 | 70.2 | 70.0 | 70.0 | 70.0 |
| 11 | F | 68.8 | 68.7 | 68.8 | 68.8 | 68.7 | 68.8 | 68.8 | 68.8 | 68.8 |
| 12 | M | 68.5 | 68.5 | 68.5 | 68.4 | 68.3 | 68.4 | 68.5 | 68.7 | 68.6 |
| 13 | F | 67.5 | 67.5 | 67.5 | 67.5 | 67.4 | 67.5 | 67.5 | 67.5 | 67.5 |
| 14 | M | 67.6 | 67.6 | 67.6 | 67.6 | 67.7 | 67.7 | 67.8 | 67.6 | 67.7 |
| 15 | F | 68.2 | 68.4 | 68.3 | 68.3 | 68.2 | 68.3 | 68.3 | 68.2 | 68.3 |

(b) Soft-shell, from August 23 to 26, 2002 (Live - Cooked - Frozen - Thawed)

| Lobster | Sex | Alive CL | | | Cooked CL | | | Frozen CL | | | Thawed CL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | Avg. | 1 | 2 | Avg. | 1 | 2 | Avg. | 1 | 2 | Avg. |
| 1 | F | 68.0 | 67.9 | 68.0 | 67.7 | 67.9 | 67.8 | 67.6 | 67.7 | 67.7 | 67.6 | 67.7 | 67.7 |
| 2 | M | 67.9 | 68.0 | 68.0 | 67.5 | 67.6 | 67.6 | 67.4 | 67.5 | 67.5 | 67.7 | 67.6 | 67.7 |
| 3 | M | 68.6 | 68.6 | 68.6 | 68.3 | 68.3 | 68.3 | 68.3 | 68.3 | 68.3 | 68.3 | 68.3 | 68.3 |
| 4 | M | 67.8 | 67.8 | 67.8 | 67.3 | 67.4 | 67.4 | 67.2 | 67.4 | 67.3 | 67.6 | 67.4 | 67.5 |
| 5 | M | 69.4 | 69.4 | 69.4 | 69.1 | 69.1 | 69.1 | 68.9 | 68.9 | 68.9 | 69.1 | 69.2 | 69.2 |
| 6 | F | 69.2 | 69.2 | 69.2 | 69.2 | 69.3 | 69.3 | 68.8 | 68.8 | 68.8 | 69.2 | 69.1 | 69.2 |
| 7 | M | 69.0 | 68.9 | 69.0 | 68.6 | 68.7 | 68.7 | 68.6 | 68.6 | 68.6 | 68.6 | 68.7 | 68.7 |
| 8 | M | 69.9 | 69.9 | 69.9 | 69.8 | 69.7 | 69.8 | 69.6 | 69.7 | 69.7 | 69.7 | 69.7 | 69.7 |
| 9 | M | 67.3 | 67.3 | 67.3 | 67.0 | 67.0 | 67.0 | 66.8 | 66.8 | 66.8 | 66.9 | 67.0 | 67.0 |
| 10 | F | 66.8 | 66.7 | 66.8 | 66.4 | 66.5 | 66.5 | 66.5 | 66.3 | 66.4 | 66.5 | 66.5 | 66.5 |
| 11 | F | 69.8 | 69.8 | 69.8 | 69.4 | 69.5 | 69.5 | 69.5 | 69.3 | 69.4 | 69.4 | 69.3 | 69.4 |
| 12 | M | 67.5 | 67.6 | 67.6 | 67.3 | 67.5 | 67.4 | 67.3 | 67.3 | 67.3 | 67.3 | 67.2 | 67.3 |
| 13 | M | 68.5 | 68.5 | 68.5 | 68.1 | 68.0 | 68.1 | 67.9 | 67.9 | 67.9 | 67.9 | 67.9 | 67.9 |
| 14 | M | 69.3 | 69.3 | 69.3 | 68.9 | 69.0 | 69.0 | 68.8 | 68.9 | 68.9 | 68.9 | 68.9 | 68.9 |
| 15 | F | 67.4 | 67.5 | 67.5 | 67.0 | 67.2 | 67.1 | 67.0 | 67.1 | 67.1 | 67.1 | 67.0 | 67.1 |

**APPENDIX 1 (*continued*)**
Raw data of CL measurements (mm)

(c) Hard-shell, from October 4 to 7, 2002 (Live - Frozen - Thawed)

| Lobster | Sex | Live CL | | | Frozen CL | | | Thawed CL | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | Average | 1 | 2 | Average | 1 | 2 | Average |
| 1 | F | 68.5 | 68.6 | 68.6 | 68.5 | 68.4 | 68.5 | 68.7 | 68.7 | 68.7 |
| 2 | F | 68.9 | 69.0 | 69.0 | 68.8 | 68.8 | 68.8 | 68.8 | 68.9 | 68.9 |
| 3 | M | 68.0 | 68.1 | 68.1 | 67.9 | 67.9 | 67.9 | 68.1 | 68.1 | 68.1 |
| 4 | F | 67.0 | 67.0 | 67.0 | 66.8 | 66.9 | 66.9 | 67.0 | 66.9 | 67.0 |
| 5 | F | 68.5 | 68.5 | 68.5 | 68.5 | 68.5 | 68.5 | 68.4 | 68.6 | 68.5 |
| 6 | F | 67.6 | 67.6 | 67.6 | 67.4 | 67.6 | 67.5 | 67.5 | 67.5 | 67.5 |
| 7 | M | 68.5 | 68.6 | 68.6 | 68.3 | 68.4 | 68.4 | 68.4 | 68.4 | 68.4 |
| 8 | M | 69.0 | 68.9 | 69.0 | 68.8 | 68.9 | 68.9 | 68.8 | 68.7 | 68.8 |
| 9 | F | 68.8 | 68.9 | 68.9 | 68.8 | 68.8 | 68.8 | 68.9 | 68.8 | 68.9 |
| 10 | F | 66.6 | 66.7 | 66.7 | 66.5 | 66.6 | 66.6 | 66.7 | 66.5 | 66.6 |
| 11 | F | 68.8 | 68.8 | 68.8 | 68.6 | 68.8 | 68.7 | 68.6 | 68.6 | 68.6 |
| 12 | M | 68.9 | 68.9 | 68.9 | 68.8 | 68.9 | 68.9 | 68.8 | 68.8 | 68.8 |
| 13 | F | 69.7 | 69.7 | 69.7 | 69.5 | 69.5 | 69.5 | 69.5 | 69.5 | 69.5 |
| 14 | M | 68.2 | 68.1 | 68.2 | 68.1 | 68.2 | 68.2 | 68.1 | 68.2 | 68.2 |
| 15 | F | 66.9 | 66.9 | 66.9 | 66.8 | 66.7 | 66.8 | 66.8 | 66.7 | 66.8 |

(d) Hard-shell, from October 4 to 7, 2002 (Live - Cooked - Frozen - Thawed)

| Lobster | Sex | Live CL | | | Cooked CL | | | Frozen CL | | | Thawed CL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | Avg.. | 1 | 2 | Avg.. | 1 | 2 | Avg. | 1 | 2 | Avg. |
| 1 | F | 67.4 | 67.3 | 67.4 | 66.8 | 67.1 | 67.0 | 66.9 | 67.1 | 67.0 | 67.1 | 67.0 | 67.1 |
| 2 | M | 67.7 | 67.7 | 67.7 | 67.2 | 67.4 | 67.3 | 67.1 | 67.2 | 67.2 | 67.2 | 67.2 | 67.2 |
| 3 | M | 69.1 | 69.2 | 69.2 | 68.8 | 68.8 | 68.8 | 68.7 | 68.6 | 68.7 | 68.9 | 68.9 | 68.9 |
| 4 | M | 69.3 | 69.3 | 69.3 | 69.1 | 68.9 | 69.0 | 68.9 | 68.9 | 68.9 | 69.0 | 69.0 | 69.0 |
| 5 | M | 68.3 | 68.3 | 68.3 | 67.8 | 67.9 | 67.9 | 67.9 | 67.8 | 67.9 | 67.8 | 67.9 | 67.9 |
| 6 | F | 67.5 | 67.5 | 67.5 | 66.9 | 67.1 | 67.0 | 67.0 | 67.0 | 67.0 | 67.1 | 67.1 | 67.1 |
| 7 | M | 69.0 | 69.1 | 69.1 | 68.6 | 68.6 | 68.6 | 68.7 | 68.7 | 68.7 | 68.7 | 68.5 | 68.6 |
| 8 | M | 67.2 | 67.1 | 67.2 | 66.8 | 66.9 | 66.9 | 66.6 | 66.6 | 66.6 | 66.8 | 66.5 | 66.7 |
| 9 | M | 68.2 | 68.2 | 68.2 | 67.8 | 67.9 | 67.9 | 67.7 | 67.8 | 67.8 | 67.9 | 67.6 | 67.8 |
| 10 | F | 69.4 | 69.4 | 69.4 | 68.9 | 68.8 | 68.9 | 68.6 | 68.5 | 68.6 | 68.9 | 68.7 | 68.8 |
| 11 | F | 69.3 | 69.3 | 69.3 | 68.8 | 68.9 | 68.9 | 68.7 | 68.8 | 68.8 | 68.8 | 68.6 | 68.7 |
| 12 | M | 69.6 | 69.6 | 69.6 | 69.1 | 69.1 | 69.1 | 69.2 | 69.2 | 69.2 | 69.2 | 69.0 | 69.1 |
| 13 | M | 69.8 | 69.7 | 69.8 | 69.6 | 69.6 | 69.6 | 69.5 | 69.4 | 69.5 | 69.1 | 69.2 | 69.2 |
| 14 | M | 68.1 | 68.3 | 68.2 | 67.8 | 67.9 | 67.9 | 67.7 | 67.7 | 67.7 | 67.6 | 67.7 | 67.7 |
| 15 | F | 68.1 | 68.1 | 68.1 | 67.8 | 67.6 | 67.7 | 67.9 | 67.8 | 67.9 | 67.8 | 67.7 | 67.8 |

## APPENDIX 2

Durometer readings at the anterodorsal region (A) and dorsolateral region (B) for the October lobsters.

| Treatment | Lobster | Sex | Durometer Readings (scale of 0 to 100) | | Shell condition |
|---|---|---|---|---|---|
| | | | A | B | |
| Freezing | 1 | F | 82 | 69 | New hard-shell |
| | 2 | F | 81 | 68 | New hard-shell |
| | 3 | F | 89 | 85 | Hard-shell |
| | 4 | F | 85 | 83 | Hard-shell |
| | 5 | F | 82 | 69 | New hard-shell |
| | 6 | M | 90 | 85 | Hard-shell |
| | 7 | F | 82 | 69 | New hard-shell |
| | 8 | M | 83 | 82 | Hard-shell |
| | 9 | F | 89 | 80 | Hard-shell |
| | 10 | F | 82 | 80 | Hard-shell |
| | 11 | M | 90 | 81 | Hard-shell |
| | 12 | M | 91 | 83 | Hard-shell |
| | 13 | M | 89 | 83 | Hard-shell |
| | 14 | M | 95 | 84 | Hard-shell |
| | 15 | M | 87 | 85 | Hard-shell |
| Cooking, then freezing | 1 | M | 81 | 69 | New hard-shell |
| | 2 | F | 89 | 69 | New hard-shell |
| | 3 | F | 88 | 78 | Hard-shell |
| | 4 | M | 87 | 81 | Hard-shell |
| | 5 | F | 83 | 78 | Hard-shell |
| | 6 | F | 81 | 79 | Hard-shell |
| | 7 | M | 89 | 84 | Hard-shell |
| | 8 | F | 85 | 80 | Hard-shell |
| | 9 | M | 90 | 85 | Hard-shell |
| | 10 | F | 83 | 78 | Hard-shell |
| | 11 | M | 90 | 81 | Hard-shell |
| | 12 | F | 89 | 80 | Hard-shell |
| | 13 | M | 90 | 85 | Hard-shell |
| | 14 | M | 89 | 79 | Hard-shell |
| | 15 | M | 89 | 80 | Hard-shell |

## APPENDIX 3

Thickness of common objects

| Thickness of common objects | Millimetres (mm) |
|---|---|
| Adhesive tape "Scotch Tape™" | 0.03 |
| Phone book page | 0.04 |
| Brown standard envelope | 0.08 |
| Human hair | 0.09 |
| Sheet of regular white paper | 0.10 |
| Side of a can of "Pepsi™" | 0.12 |
| Grain of white granulated sugar | 0.30 |
| Side of a waxed-cardboard "Tim Horton™" coffee cup | 0.37 |
| Standard paper staple | 0.42 |
| An average human finger nail | 0.49 |
| Pencil lead HB 0.7 | 0.69 |
| Credit card (without the printed numbers) | 0.81 |
| Standard paper clip | 0.84 |
| 10¢ Canadian coin | 1.08 |
| CD | 1.51 |
| 1¢ Canadian coin | 1.55 |
| 25¢ Canadian coin | 1.55 |
| 5¢ Canadian coin | 1.72 |
| $ 2 Canadian coin | 1.76 |
| $ 1 Canadian coin | 1.83 |
| Computer floppy disc | 2.86 |